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ABSTRACT

A criterion-referenced approach to a physical science course for nonmajors was implemented at Rhode Island Junior College. The basic unit of knowledge for this study was motion and the related topics of force, work, energy, power, and momentum. At completion, each student was expected to exhibit the ability to: (1) use energy more efficiently, (2) provide better for his own safety and the safety of others, and (3) have greater appreciation for the interrelationship of all forms of energy. Instruction was designed to allow mastery by each student. Students could repeat mastery exams until they achieved a mark for evaluation that met their own aspirations for the course. Tables and graphs are used to indicate the success of the criterion-referenced approach as opposed to the norm-referenced approach, which was used for this course previously. When results from an evaluation exam given to students from both approaches were compared, the criterion-referenced group averaged 10 points higher than the norm-referenced group. In addition, the criterion-referenced group expressed high satisfaction with the course and indicated a desire to take more courses using the same approach. (MJK)

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A Comparison of Criterion-Referenced and Norm-Referenced Approaches to the Teaching of Physical Science

by

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A Practicum Presented to Nova University in Partial Fulfillment of the Requirements for the Degree of Doctor of Education

Nova University

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NTRODUCTION

Physical Science is a course originally designed for broadening he background of those students who are not majoring in the natural ciences or related areas. Until a year ago all liberal arts majors t Rhode Island Junior College were required to take two semesters equentially in a natural science area of their choice. Now they re not required to complete even a single semester science offering. or the physical science course to survive, it must effectively com- ete with other electives (science and non-science) in an atmosphere here science enrollment has been rapidly declining.

This investigation was undertaken to:

(1) provide students of varying learning speeds with an opportunity for success and enjoyment;

nd (2) increase physical science enrollment in future semesters.

Until this semester, the classroom instructional pace has been imed at the average learning rate of the students, and the testing as been used to assess individual student performance - a norm- eferenced approach. During this past semester, instruction was aried for students with different learning speeds, and students ere allowed to take unit tests several times until they were atisfied with their performance - a criterion-referenced approach.[1] his criterion-referenced approach is sometimes called the systems pproach.

This systems approach was successful enough that it is now being sed for:

(1) other units of study in physical science,

(2) other courses taught by this instructor,

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nd (3) a course taught by the Music Department.

The results of this study will be shared with many other depart-ents at Rhode Island Junior College, particular emphasis will be iven to the elective courses in natural science - chemical science, iology, geology, and astronomy.

ACKGROUND AND SIGNIFICANCE

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In order to evaluate students' performance with respect to ourse objectives, the norm-referenced approach has been traditional.[2] sing such an approach a teacher will use testing to determine a stu- ent's performance in relation to the performance of others. In ddition, he will usually use a normal curve in assigning grades and onsider aptitude as the capacity for learning.

This study seeks to compare this approach to a criterion-refer- nced approach,[3] where testing is used to measure one's performance gainst criteria established prior to the learning activities. nstruction provides many different and alternative learning activi- ies to take into account students who learn at different rates. This llows for mastery of the subject matter to nearly all of the students; he only ones who do not achieve the mastery criteria are those who ill not persist in the effort. Aptitude gives an indication of the ime necessary for the student to meet the stated objectives.

To make the criterion-referenced approach operationally effective he teacher must establish a rationale for each unit of study which onvinces the student that learning is worthwhile to him. The testing ust be designed to measure the behavioral objectives, whether the bjectives are designed by the teacher alone or by the teacher and tudents working cooperatively.[4]

Perhaps over 90% of our students can master what we have to teach hem if they are given sufficient time and means with which to do it.[5] ur democratic society must find ways to achieve mastery in education- l endeavor to maintain itself at full effectiveness in an ever ncreasingly complex society.

Carroll[6] states that if students are normally distributed th respect to aptitude in a subject area and are provided with e same amount, quality, and time of instruction, then an achieve- nt test will show a normal distribution. But if instruction is de appropriate to the needs of each student, the relationship tween aptitude and achievement will approach a zero correlation efficient. Aptitude is then found to correlate well with how st mastery is achieved.

For the teacher, conducting a criterion-referenced approach learning within a conventional A, B, C, D, F grading system pre- nts certain problems. Students have become conditioned by norm- ferenced convention as evidenced by statements like "I'm only a science student". Such students do not believe that mastery is ssible, and seem resigned achieving a C mark. A primary task of e teacher is to convince students that an A mark is within ssibility for all students.

By traditional norm-referenced pre-conditioning, some students ntinue to look for ratings relative to other students. Those who arn more slowly require longer times and more alternative learning tivities to achieve mastery. Some of these students tend to feel dly about learning slowly although no stigma is attached to them by e instructor. Some who have part-time employment resent the added me necessary to achieve mastery, and a few even worry about being aded downward on achievement. The teacher must be vigilant to scern these attitudes and convince these students of their potential r mastery without penalty.

A third problem within present structures is the rigid time system

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rimester, semester or quarter). In order to receive credit
ward graduation, a student must meet the course objectives within
specified time.

Perhaps all three of the above problems could be solved by
olishing the rigid time system and using a periodic reporting
heme that utilizes a one-point grading system[7] - a pass or incom-
ete. The incompletes could be eventually changed to pass and no
completes would be reported outside the registrar's office.
ch a no-penalty system could produce a favorable attitude from
st students, the evidence being their behavior in terms of what
ey say about the course and the school.[8] Further evidence of success
such a system could be seen if the students achieved mastery as
monstrated by properly designed criterion-referenced tests.[9] Even
ese changes could fail to produce favorable attitudes among students
their individual characteristics, desires, and needs are not
nsidered in curriculum decisions.[10]

Most of the concepts of the criterion-referenced or systems approach
ve been tried successfully by the following colleges:

(1) Moraine Valley Community College, Palos Hills, Illinois.

(2) Brookdale Community College, Lincroft, New Jersey.

(3) Central Piedmont Community College, Charlotte, North Carolina.

(4) Mitchell College, Statesville, North Carolina.

d (5) Kittrell Junior College, Kittrell, North Carolina.

veral other community colleges are well on the way toward utilizing
e teaching processes outlined here.

The most definitive results (in terms of actual data) so far have
curred at Brookdale in which 90% of the students who enrolled for the
rst time in September, 1971, completed the school year.

OCEDURES

The basic unit of knowledge used for this study was motion and e related topics of forces, work, energy, power, and momentum. e rationale for this study of motion is its application to the udent's encounter in everyday life.

To be more specific, after completing this unit, each student s expected to exhibit the ability to:

(1) more efficiently use energy (gasoline, electricity, etc.) to help meet the existing energy crisis,

(2) provide better for his own and others' personal safety,

(3) have greater appreciation for the interrelation of all forms of energy that affect the decisions he makes almost daily.

In an attempt during this semester to meet individual learning eeds, the following changes were made:

(1) Additional laboratory and class hours were provided to discuss problems either for each individual or in a small group setting. About three-fourths of the students took advantage of this.

(2) Greater amounts of class time were used to explore alternative solutions to everyday motion problems, such as the applications of Newton's laws of motion, energy balances, and momentum balances.

(3) Instructional films on forces and momentum were introduced in the classroom along with a demonstration showing velocity and acceleration for circular motion. Students became actively involved in the demonstrations.

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and (4) Students had an opportunity to view two videotapes (Newton's 1st and 2nd laws, energy balance, and momentum balance) during non-class hours. Approximately one-half of the students viewed these tapes.

Less class time was devoted to straight lecturing.

After using about four weeks to study the basic principles of motion with applications, a diagnostic test[12] (multiple choice and essay questions) was given so that the student could assess those topics in which he was deficient. The teacher used class time following this to analyze each question on the diagnostic test and to provide additional help for further student questions which the diagnostic test provoked.

A mastery test[13] was given one week after the diagnostic test covering the same subject matter - motion. The mastery exam was designed to detect those areas in which the student had become proficient. It was expected that each student would do better on the mastery test than on the ~~achievement~~ diagnostic test.

Any student who wished to do so could take make-ups on the mastery test again and again until he achieved a mark for evaluation that met his own personal aspirations in the course. The highest mark each student achieved on any of these exams was the one used for his course evaluation.

The exam results for this semester (criterion-referenced approach) were compared with those of last semester (norm-referenced approach) using a statistical t-test comparing the means. The t-test was selected because it is unlikely that a universal standard deviation is known from the samples involved (45 students last semester and

30 students this semester).

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SULTS

Table 1, 2, and 3 below summarize the frequency distributions test scores for last semester, this semester (diagnostic), and is semester (mastery), respectively. The test for last semester s similar in content and difficulty to the mastery test given is semester.

Table 1

requency Distribution of 45 Last Semester Scores (Norm-Referenced Group)

Interval	Frequency
31-40	3
41-50	1
51-60	5
61-70	13
71-80	14
81-90	9

Table 2

requency Distribution of 26 Diagnostic Test Scores (Criterion-Referenced Group)

Interval	Frequency
11-20	2
21-30	2
31-40	4
41-50	9
51-60	5
61-70	2
71-80	1
81-90	1

Table 3

requency Distribution of 30 Mastery Test Scores (Criterion-Referenced Group)

Interval	Frequency
41-50	1
51-60	2
61-70	3
71-80	7
81-90	11
91-100	6

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These data are more graphically represented in the histograms (with frequency polygons represented by the dotted lines) in Figures 1, 2, and 3.

Depth study of these histograms reveals something approaching a normal distribution for the diagnostic test (criterion-referenced group). However, both the last semester scores (norm-referenced) and mastery test scores (criterion-referenced) have no upper tail such as usually associated with a normal distribution. This deviation from a normal distribution was expected for the criterion-referenced group; with every student having an opportunity for unlimited make-ups, the final distribution should eventually become flat (all students above 90) instead of normal. The deviation from normal for the norm-referenced group was a surprise. Perhaps the instruction at that time was well received by a majority of students, with the test scores bunching together near the top of the range.

The criterion-referenced group did much better on the mastery test (mean=78.36) than on the diagnostic test (mean=46.8) as was expected.

More important than this is the comparison of the mastery test scores for the criterion-referenced group with the test scores for the norm-referenced group. The criterion-referenced group averaged 78.36 compared with 68.63 for the norm-referenced group. The difference between these two means in favor of the criterion-referenced group is statistically significant, as shown in Table 4.

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HISTOGRAM OF THE 45 LAST SEMESTER SCORES

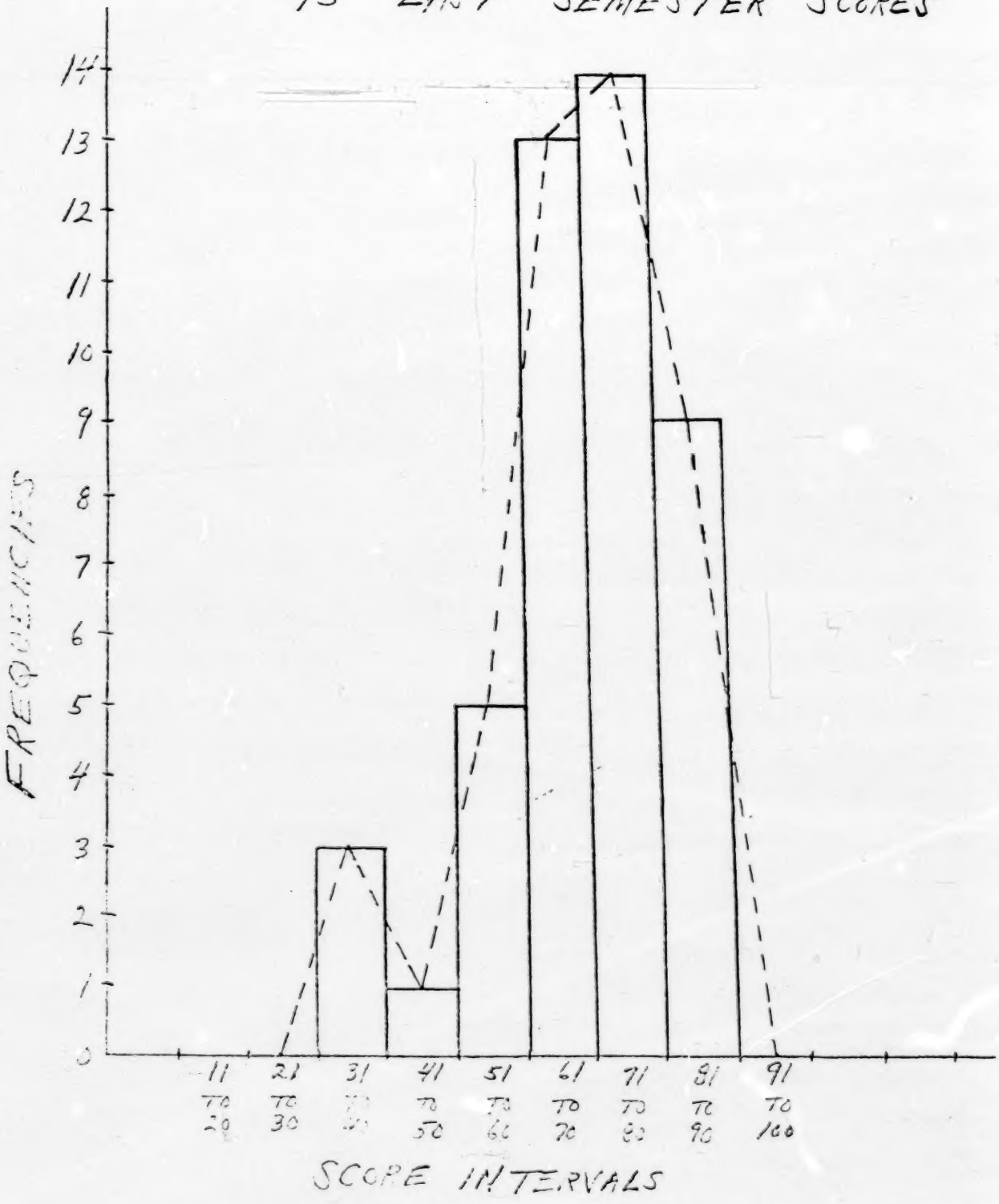

FIGURE 1.

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HISTOGRAM OF THE 26 DIAGNOSTIC TEST SCORES

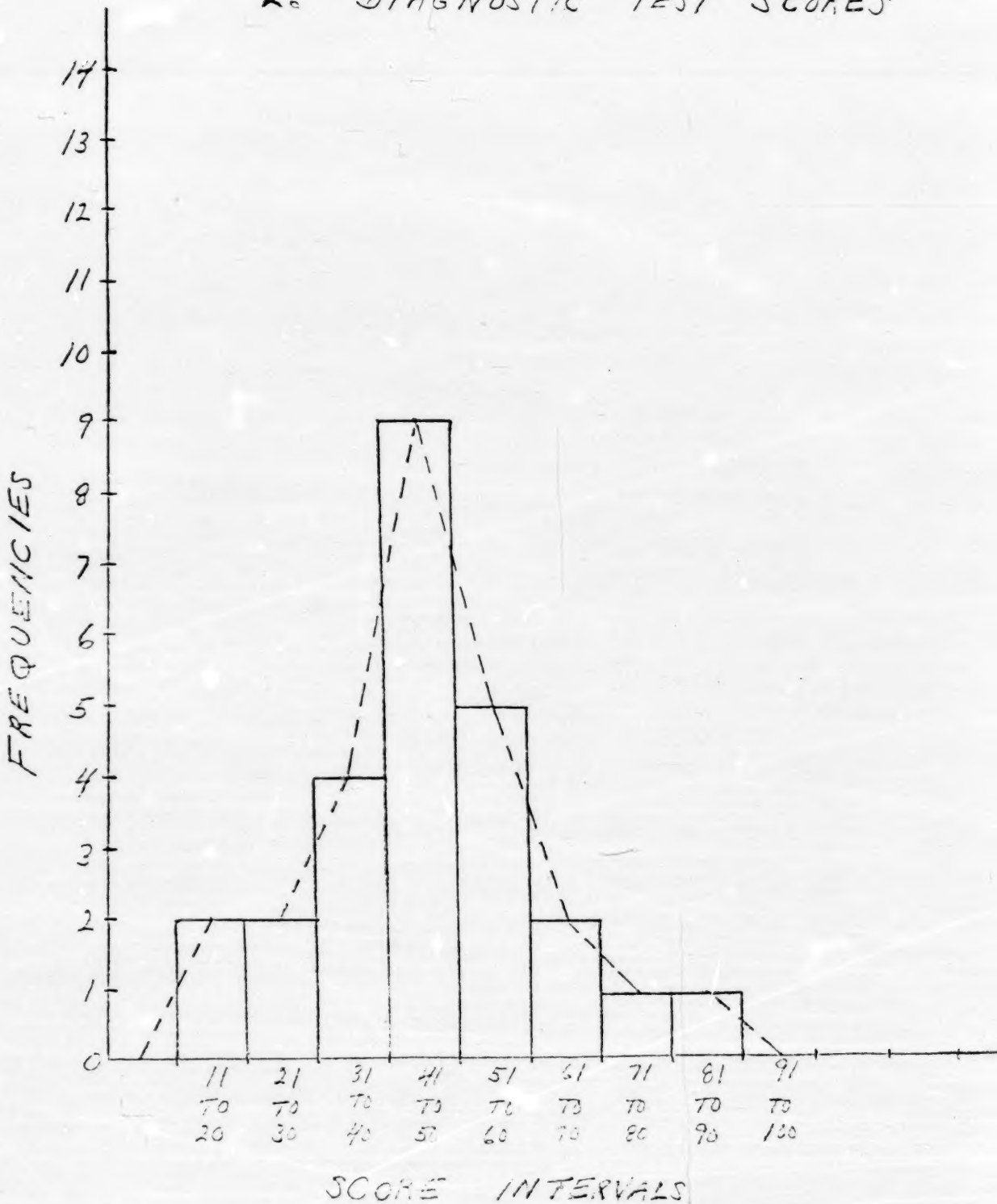

FIGURE 2.

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HISTOGRAM OF THE 30 MASTERY TEST SCORES

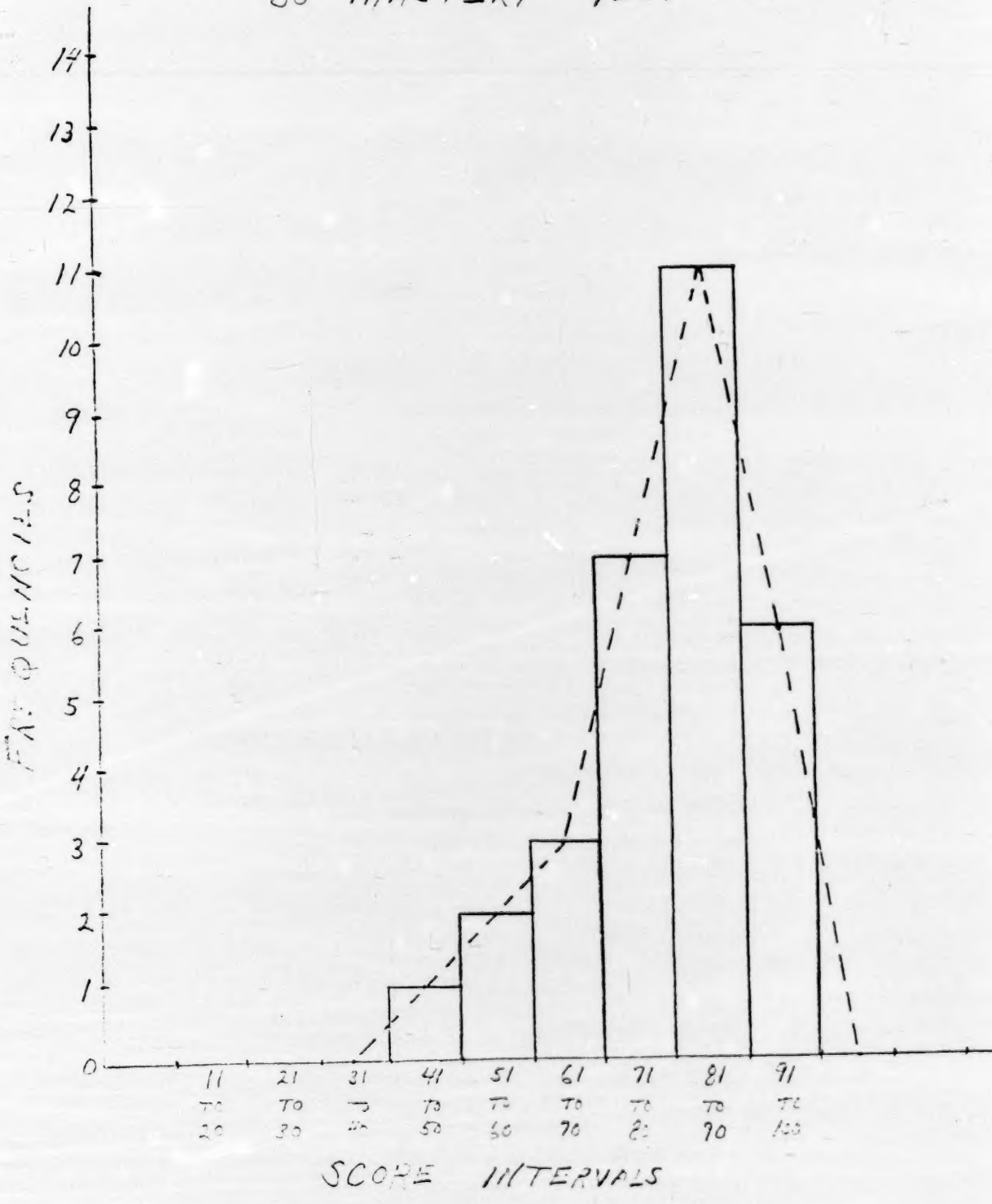

FIGURE 3.

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Table 4

Comparison of Academic Performance

	Norm-Referenced Group (45 Students)	Criterion-Referenced Group (30 Students)
Arithmetic Mean (100=perfect score)	68.63	78.36
Standard Deviation	12.62	13.66
Range in Which True Mean Falls (95% Confidence Limits)	64.95 to 72.31	73.27 to 83.45

(For more details on the t-test comparing the norm-referenced group with the criterion-referenced group, see the appendix.)

In addition to better academic performance, the criterion-referenced group was also happier with the course. All 30 students in this group stated in their course evaluations that they preferred the criterion approach to the norm approach they experienced in other courses. Also all 30 indicated that, if given a choice, they would take another course with this instructor. Only 39 of the 45 of the norm-referenced group stated this same preference.

From the instructor's viewpoint, only two diappointments were encountered with the approach of allowing students unlimited make-up exams:

(1) Eleven students of the 30 did not bother to take any make-up exams.

(2) Twelve of the 19 who did take make-ups procrastinated until the last week of the semester. (This unit of study took place in the first five weeks of the semester.) Half of these twelve needed two or more make-ups in order to raise their test scores.

RECOMMENDATIONS

The encouraging results of the criterion-referenced approach have already led this instructor to using it for the other units of the physical science course in addition to all other courses that this instructor teaches. A music teacher at the college heard about this approach and is using it now; he is quite enthusiastic about it.

This instructor will continue to use and evaluate this systems approach next semester with the following additions:

(1) Several more appropriate films and demonstrations will be used in the classroom work.

(2) Videotapes will be made covering all aspects of the course to be used by students during non-class hours.

(3) Added laboratory experiences will be provided for those students who desire them.

(4) Students will be more vigorously encouraged to take advantage of make-up exams, and to do so within two weeks of the first mastery test while the subject matter is still fresh in the mind. A target grade of 80% on the exam will be recommended.

(5) Students will be encouraged to seek advice from other students who have experienced the criterion-referenced approach.

By communicating with other departments through department chairmen, the author will make use of this report to encourage others to experiment and evaluate the systems approach to instruction. Science departments will be emphasized. Careful writing of rationale and objectives will be emphasized. A sharing of the results among departments will be requested.

Should all these new studies continue to show positive results for the systems approach, the administration of the college will probably summarize the results and make them available to the entire faculty.

FOOTNOTES

1. Barton R. Herrscher, Implementing Individualized Instruction, Archem Company, Houston, 1971, pp. 4-5.
2. Ibid, page 8.
3. Ibid,
4. Ibid, pp. 5-6.
5. Benjamin S. Bloom,"Learning for Mastery", from Evaluation Comment (a publication of the Center for the Study of Education, UCLA), vol. 1, no. 2, May 1968, pp. 1-11.
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7. John M. Flynn, Learning Theory and Applications, Nova University, Fort Lauderdale, Florida, 1973, page 358.
8. Robert F. Mager, Developing Attitude Toward Learning, Fearon Publishers, Palo Alto, California, 1968, page 15.
9. W. J. McKeachie, "Research on Teaching at the College and and University Level", from Handbook of Research in Teaching, N. L. Gage, editor, Rand McNally, Chicago, 1963, pp. 1124-1125.
10. Lewis B. Mayhew and Patrick J. Ford, Changing the Curriculum, Jossey-Bass, San Francisco, 1971, page 15.
11. John E. Roueche, in collaboration with John C. Pitman, A Modest Proposal: Students Can Learn, Jossey-Bass, San Francisco, 1972 pp. 114,-119.
12. Flynn, op. cit., page 333.
13. Ibid.
14. Bloom, loc. cit.

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APPENDIX

Testing the Significance of the Difference Between the Sample Means

(Norm Referenced and Criterion-Referenced)

1. Null Hypothesis:

The two sample means do not differ significantly.

$$H_o: \bar{X}_1 = \bar{X}_2$$

2. Alternative Hypothesis:

The two sample means do significantly differ.

$$H_a: \bar{X}_1 \neq \bar{X}_2$$

3. Desired level of Significance:

$$\alpha = .05$$

4. Degrees of Freedom:

$$df = n_1 + n_2 - 2 = 45 + 30 - 2 = 73$$

5. Critical t-value:

For two-tailed test, $\alpha = .05$ and $df = 73$ gives t-value of 1.96. Therefore, reject H_o and accept H_a if $t > +1.96$ or $t < -1.96$

6. $$t = \frac{\bar{X}_1 - \bar{X}_2}{s_p\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \qquad \text{where: } s_p = \sqrt{\frac{\Sigma(X_1 - \bar{X}_1)^2 + \Sigma(X_2 - \bar{X}_2)^2}{n_1 + n_2 - 2}}$$

$\bar{X}_1 = 68.63$ $\quad \bar{X}_2 = 78.36$

$n_1 = 45$ $\quad n_2 = 30$

$\Sigma(X_1 - \bar{X}_1)^2 = 7,007.41$

$\Sigma(X_2 - \bar{X}_2)^2 = 5,413.76$

$s_p = 13.04$

$t = -3.16$

The null hypothesis is rejected and the alternate hypothesis is accepted. The two sample means do differ significantly.